GGUM2004 Windows User's Guide

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The GGUM2004 program has been tested on a variety of data sets. However, the authors assume no responsibility or liability for the accuracy of its results. This software and its associated documentation are provided free of charge, but users are asked not to distribute copies of the program to others. **Free copies of the most current version of the program are available via the Internet at:**

http://www.education.umd.edu/EDMS/tutorials/index.html

Individuals who publish results from this program are asked to cite Roberts, Donoghue & Laughlin (2000) and Roberts, Fang, Cui and Wang (2004). Please report any problems encountered with the program to James S. Roberts (jrobert4@umd.edu).

The GGUM2004 Windows Interface

GGUM2004 has a Windows-based graphical user interface that is designed to make the program user-friendly. The interface provides a means to easily create GGUM2004 command files that are subsequently passed to the core FORTRAN

estimation program. The interface then waits for the FORTRAN program to provide results that are ultimately displayed by the interface using both text and graphics windows. Command files that are created using the graphical interface can be saved to disk and subsequently read by the interface at a later time if you wish to rerun a given analysis.

Although the interface provides an easy mechanism to generate GGUM2004 command files, these files can also be created manually using an ASCII text editor (e.g., Notepad, WordPad, DOS Edit, etc.). Alternatively, a command file can be initially created and saved using the graphical interface, and then the file can be altered with any ASCII editor. A GGUM2004 command file can be executed using the graphical interface, or it can be manually submitted to the FORTRAN estimation program. Instructions for manually submitting command files to the FORTRAN program are given in the GGUM2004 Technical Reference Manual. (The GGUM2004 Technical Reference Manual is provided with the program in the "C:\GGUM2004\MANUAL" folder.)

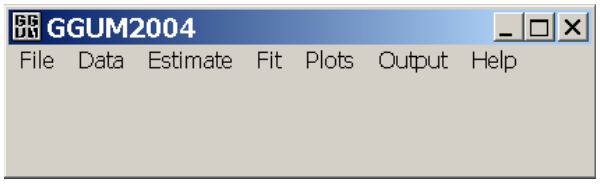
When compared to its predecessor (GGUM2000), the GGUM2004 program has several new features in addition to the new graphical user interface:

1) The number of response categories can vary across items.
2) The estimation algorithm will accommodate missing item responses under the assumption that they are missing at random.
3) The program implements several new indices of item fit and also calculates information criteria for each model that is analyzed.
4) The program produces several types of diagnostic and informative graphics output to assist the user in choosing the appropriate model for a given application.

The remainder of this document describes various aspects of the GGUM2004 graphical user interface. For details about the estimation procedures used in the program or about specific syntax in command files, the reader should consult the GGUM2004 Technical Reference Manual.

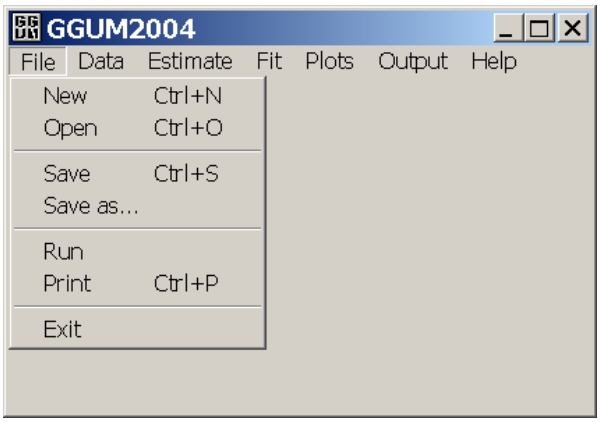
1. The Main Menu

After activating the GGUM2004 graphical user interface, the main menu will appear on the computer screen. The main menu has seven pull-down menus: **File**, **Data**, **Estimate**, **Fit**, **Plots**, **Output**, and **Help**. Each pull-down menu corresponds at a different aspect of fitting or diagnosing the Generalized Graded Unfolding Model (GGUM) proposed by Roberts, Donoghue & Laughlin (2000).

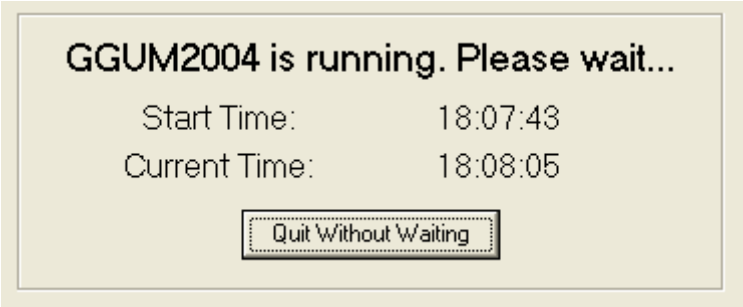


2. The File Pull-down Menu

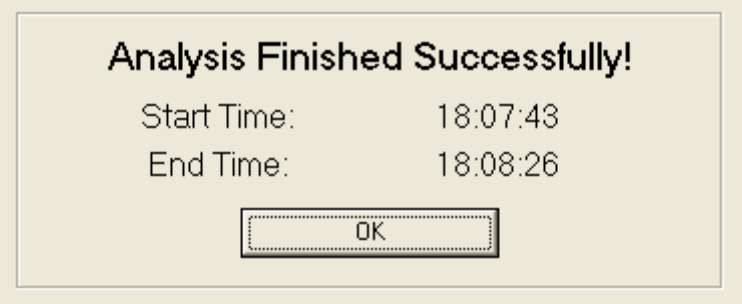
The **File** pull-down menu has seven options: **New**, **Open**, **Save**, **Save As**, **Run**, **Print** and **Exit**. The **New** option is used to clear all the current settings from the interface and reset them to any default values that may exist. The **Open** option is used to open a preexisting command file from a disk location. Once a command file is created, you can save it to disk using the **Save** or **Save As** options. It is always prudent to save your file prior to running the estimation program. The command file can also be printed using the **Print** option.



The **Run** option is used to begin the parameter estimation procedure (i.e., execute the core FORTRAN estimation program) after setting up a command file. As soon as you click on the **Run** option, a dialog window will pop up and display the message "GGUM2004 is running. Please Wait…" along with the "Start Time" (i.e., the time at which the program began running) and the "Current Time". Click on the "**Quit Without Waiting**" option if you wish to terminate the estimation process before it normally completes.



When GGUM2004 finishes the parameter estimation process, an "Analysis Finished Successfully" message will be written to the dialog window along with the "End Time" (i.e., the time at which the program ended). When you click on the "**OK**" option, the dialog window will disappear and the output text files and graphics can be viewed, saved, and printed using the **Output** pull-down menu.

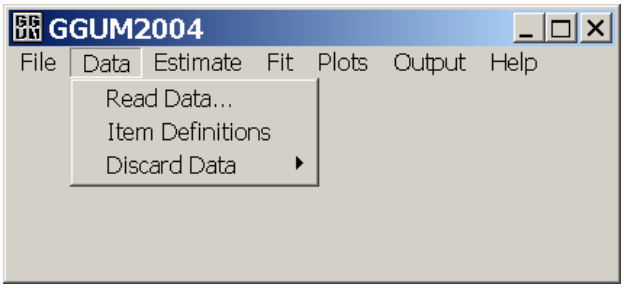


Note that all output text and graphics files are temporary files. They are deleted whenever the **New**, **Open**, **Run**, or **Exit** options are chosen. In the event that an analysis terminates abnormally, an error message will usually be written to the dialog window, and you can stop the analysis. However, this message will only appear when the error in question has been anticipated by the GGUM2004 programmers. There may be errors that have not been anticipated. In these cases, the FORTRAN estimation program will halt, but the graphical interface will continue to display the "GGUM is running. Please wait…" message in the dialog window. Most data sets can be analyzed within 10 minutes or less using default analysis option settings. Generally speaking, if the "GGUM is running. Please wait…" message has remained in the dialog window for more than 10 minutes, then the FORTRAN estimation program has, in all likelihood, abnormally terminated, and you should click on "**Quit Without Waiting**". In these cases, it may be possible to determine the cause of the error by running the FORTRAN program in a DOS window and looking for any errors that are automatically generated. These cases should also be reported to the program authors so that the appropriate error handling messages can be incorporated into the program.

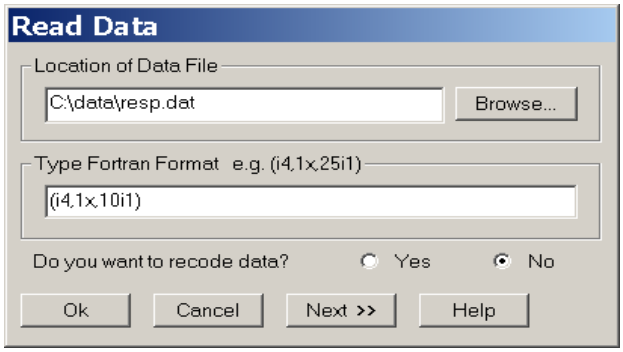
The last option on the **File** pull-down menu is the **Exit** option. When this option is chosen, all temporary output and plot files will be erased and the interface will close.

3. The Data Pull-down Menu

The **Data** pull-down menu provides three options: **Read Data**, **Item Definitions** and **Discard Data**. These options are used to specify the location, format and particular characteristics of the data to be analyzed by GGUM2004.



The **Read Data** option window allows you to specify the name and location of the item response data set to be analyzed. It also allows you to recode the data so that item responses begin with the number 0 (where 0 represents the strongest level of disagreement).



Follow the three steps to read in your data and specify the data format:

a) First, specify the drive, path, and filename of the item response data file to be analyzed. This information can be typed manually or, alternatively, the "**Browse**"

option can be used to identify the file. For example, if your data file is located in the Windows folder called "C:\DATA" and the filename is "RESP.DAT", then type:

c:\data\resp.dat

into the first text box in the **Read Data** option window. The name and location of the data file are not case sensitive.

b) Secondly, specify the format of all variables you want to read into the program using a FORTRAN format statement. The data read by GGUM2004 should be stored in an ASCII file. The corresponding FORTRAN data format should include a subject ID format specifier followed by multiple item format specifiers. The subject ID variable should be read with an integer (Ix) format no longer than 4 digits, and this variable should be read from the data record first. The format for each item response field should always be either I1 (one digit) or I2 (two digits). You can read responses from as many as 100 items in a single analysis. As with all standard FORTRAN formats, each specifier should be separated by a comma and the entire format should be enclosed in parentheses. For example, suppose your data contained a subject ID in the first 4 columns, a blank in the 5th column and then a string of single digits in the next 10 columns corresponding to the items that are to be read. To specify this data format in GGUM2004, type:

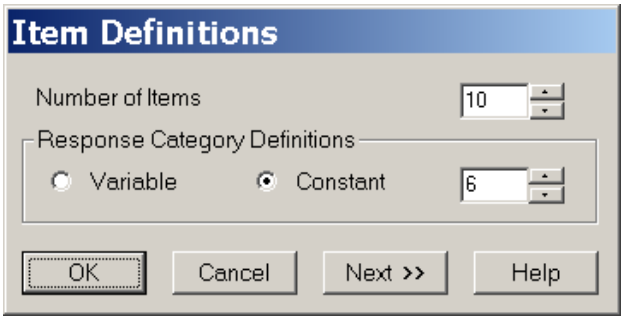
(i4,1x,10i1)

into the second text box in the **Read Data** option window. More information about FORTRAN format specifiers is contained in the help window associated with this option screen.

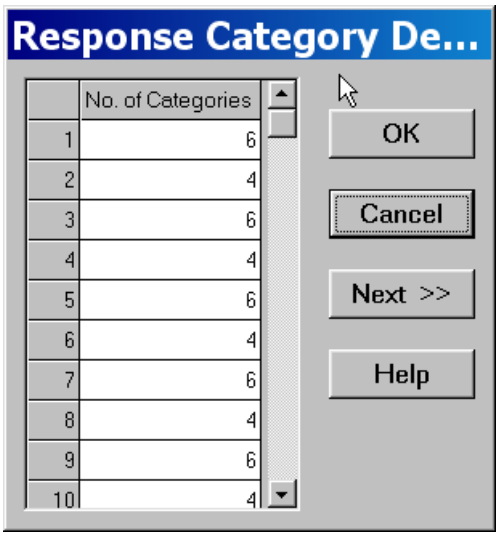
The GGUM2004 program offers an advantage over its predecessor by allowing for missing item response data that are presumed to be missing at random. ***Missing item responses should be coded as -9.*** Therefore, item response variables that contain missing data will need to be read using an I2 FORTRAN format specifier.

c) Finally, you should specify whether the data are to be recoded. The FORTRAN estimation program expects that response categories will always be coded from 0 to C_i, where 0 represents the strongest level of disagreement and C_i represents the strongest level of agreement for the *ith* item. However, researchers will often code this type of data from 1 to $C_i + 1$. The recode option will allow you to subtract 1 from every item response which will, in turn, recode responses entered from 1 to $C_i + 1$ so that they range from 0 to C_i. To recode your data, click on the "**Yes**" button for the recode feature. If your data are already coded as 0 to C_i, then highlight the "**No**" option. The default value is "**No**".

When you finish specifying the location, format and recode option for your data, then you can move to the **Item Definitions** option window either by clicking on **Next** or by clicking on **OK** first, and then clicking on the **Item Definitions** option on the **Data** pull-down menu. The **Item Definitions** option window has two functions. It allows you to define the number of item response variables that are to be read using the FORTRAN format specified in the **Read** option window. You can either type the number of items into the corresponding text box or use the vertical bars on the right side of the text box to select the desired number of items. ***The number of items read by the program should always be less than or equal to 100.*** The **Item Definitions** window also allows you to specify whether the number of response categories is constant for each item. If the

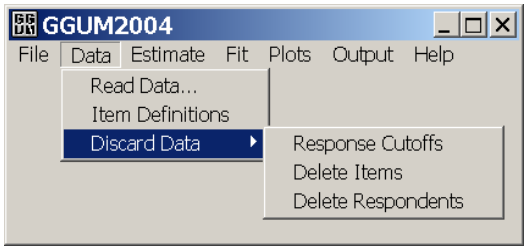


number of response categories is constant for all items, then you should click on the "**Constant**" button (default) and then indicate the number of response categories in the text box to the right of the option window. You may manually type this number into the text box or use the vertical arrows to the right of the text box to select the number. ***The number of response categories should range from 2 to 10.*** Alternatively, if the number of item response categories varies across items, then the "**Variable**" button should be highlighted. After highlighting the "**Variable**" button, click **Next**. The **Response Category Definitions** window will then appear:



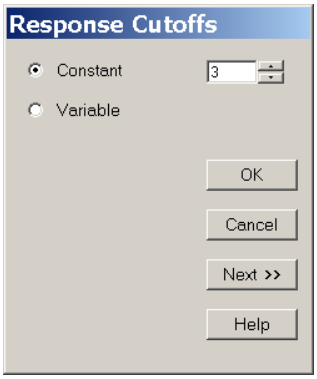
You should specify the number of response categories for each item in this window. This value can be manually typed in each box. Alternatively, double clicking on a box will yield a pull-down menu from which the appropriate number of response categories can be chosen. After specifying the number of response categories (be they constant or variable response categories), click on the **Next** button to proceed to the **Response Cutoffs** option window. Alternatively, your can click on **OK** first, and then choose the **Discard Data** option from the **Data** pull-down menu.

The **Discard Data** menu provides three options for eliminating items and/or respondents from the analysis. The first of these options is the **Response Cutoffs** option.

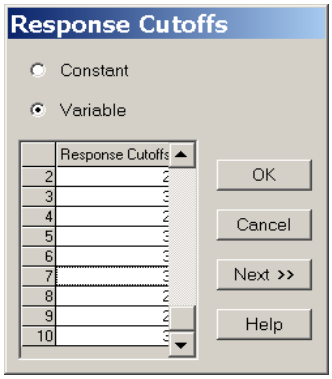


Past research has shown that if a respondent does not exhibit at least a minimal amount of agreement with some item, then the respondent cannot be measured precisely. Therefore, GGUM2004 implements a minimum item score cutoff. If an individual does not meet or exceed the value of the cutoff for at least one item in the analysis, then the individual will be discarded from the analysis. Note that the cutoff is specified using a 0 to C_i scale, where 0 is the strongest level of disagreement and C_i is the strongest level of agreement. In other words, the cutoff represents a minimum level of agreement after any response recoding has been performed.

The **Response Cutoffs** option window will appear when the **Response Cutoffs** option is selected from the **Discard Data** menu. The response cutoff will often be constant for all items. In such cases, you would simply click on the "**Constant**" button and specify the response cutoff in the text box located on the right side of the **Response Cutoffs** option window. This can be done by typing the response cutoff in the text box manually or by clicking on the vertical arrows to the right of the box.

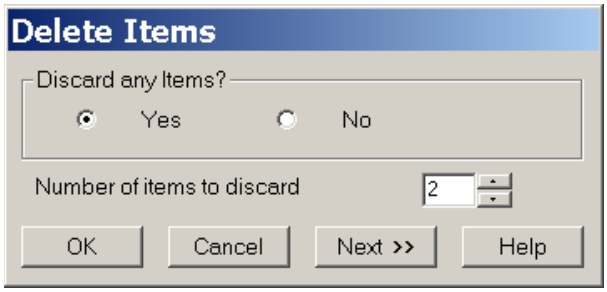


If the cutoff varies from item to item, then you should click on the "**Variable**" button. This action will automatically display a new window where you can specify the response cutoff for each item separately. Type the response cutoff value into the text box associated with each item or double click on a box to display a pull-down menu from which the cutoff can be chosen.



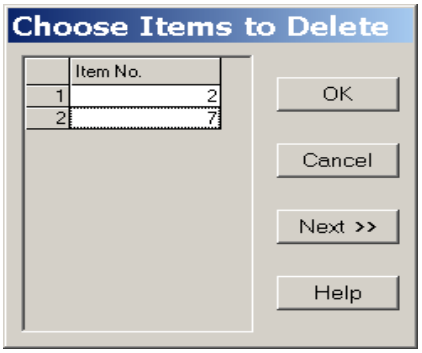
After specifying the appropriate response cutoff(s), you can click "**Next**" to move to the next option window or click on "**OK**" to return to the main menu.

The next window in the **Discard Data** option sequence is the **Delete Items** option window. This option window allows you to discard items from the parameter estimation process. If you want to analyze all of the items that were read by the GGUM2004 program, then click on the "**No**" button followed by "**OK**" or "**Next**".



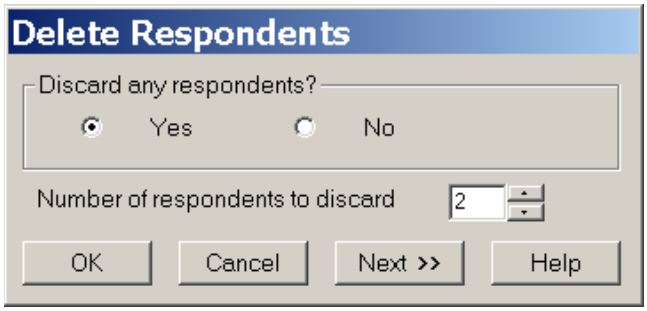
Alternatively, if you want to discard some items from the analysis, click on the "**Yes**" button. If you select "**Yes**", then you subsequently need to indicate the **Number of items to discard** in the text box on the right of the window. This number is the total number of the items that you want to eliminate from the analysis. You can manually type this number in the text box or use the vertical arrow bars to select it. Once you have chosen the number of items to discard, click on "**Next**" and the **Choose items to delete** window will automatically appear. This option window will allow you to specify the particular items to be deleted from the analysis. There is a separate cell for each deleted item. The number of cells corresponds to the number of items you requested to delete on the previous screen. To delete an item, type in its item (sequence) number into any of the available text boxes. The item (sequence) number is simply the sequence number in

which the item was read by the FORTRAN format (e.g., "2" is the second item that was read, "7" is the seventh item that was read, etc.)

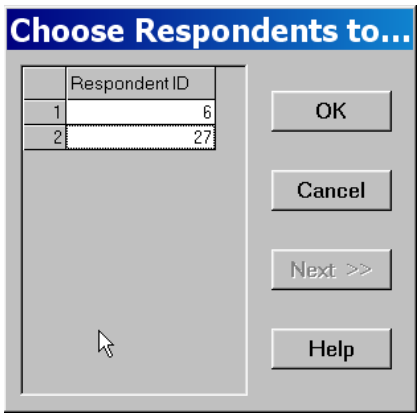


When you have finished specifying the items to delete, then click on "**OK**" to return to the main menu or click on "**Next**" to go to the next option window in the **Discard Data** sequence.

The final option window in the **Discard** Data sequence is the **Delete Respondents** option window. GGUM2004 enables you to select particular respondents to discard from the parameter estimation process. If you want to include all respondents' data in your analysis, then select the "**No**" button followed by "**OK**". If you want to eliminate some



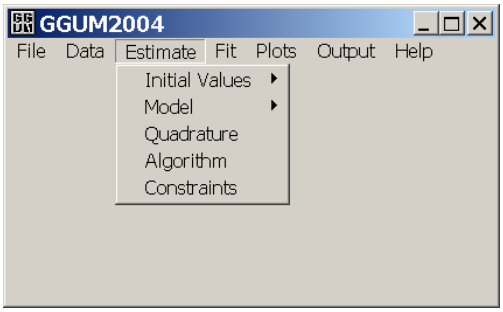
respondents from your analysis, then select the "**Yes**" button. You should then type the number of respondents you would like to discard from the analysis in the text box located on the right of this window. You can also select this number using the vertical arrows. Click on "**Next**" and then the **Choose Respondents to Delete** window will automatically



appear. Type the subject ID number for each respondent you wish to delete from the analysis into one of the cells in the "Respondent ID" column. There is a separate cell for each respondent to be deleted. The number of cells corresponds to the number of respondents you requested to delete on the previous screen. Make sure you fill every cell with a unique subject ID number, and then click "**OK**".

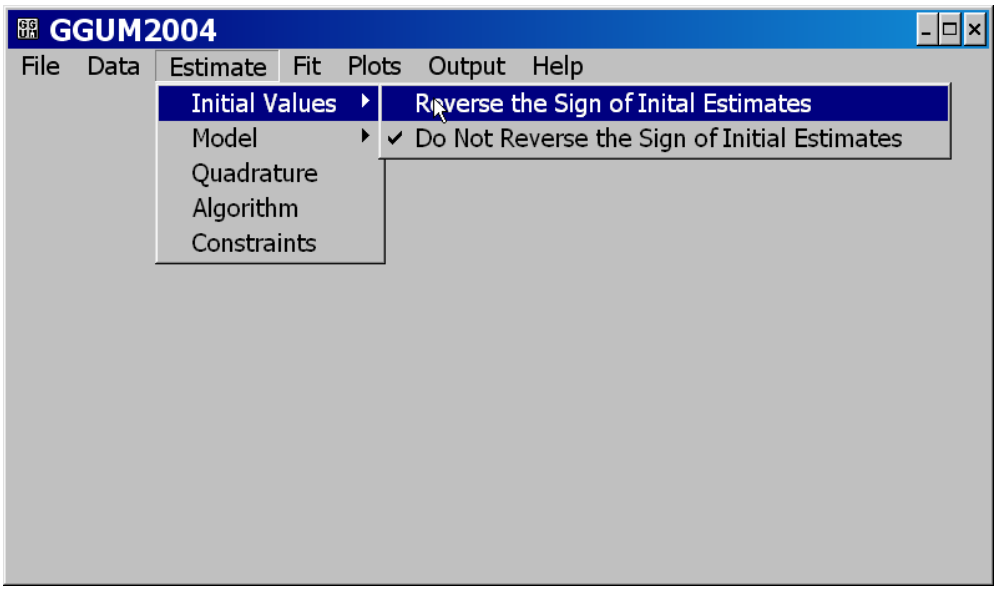
4. The Estimate Pull-down Menu

GGUM2004 estimates item parameters using a marginal maximum likelihood approach (Bock & Lieberman, 1970; Bock & Aitkin, 1981). The solution algorithm parallels Muraki's (1992) procedure used in the generalized rating scale model and is based on an expectation-maximization (EM) strategy. Detailed information about the algorithm and procedure can be found in the GGUM2004 Technical Reference Manual.



The **Estimate** pull-down menu contains 5 options that enable you to control various aspects about how the estimation process is conducted. Each of these options will be discussed in detail below.

The first option on the **Estimate** pull-down menu is the **Initial Values** option. The signs of item locations in an unfolding model are always arbitrary. GGUM2004 obtains the signs for the initial item locations from a principal components analysis of the interitem correlation matrix. However, all of these signs could be reversed without affecting the likelihood of the responses under the model. Therefore, it is a matter of choice as to which pole of the bipolar latent continuum should be labeled as "+" or "-". The signs at the poles of the latent continuum can be reversed by simply reversing the signs of the initial item locations. This can be accomplished by selecting the **Initial Values** option from the **Estimate** pull-down menu and then choosing "**Reverse the Sign of Initial Estimates**".



GGUM2004 can estimate 8 alternative models in the GGUM family. Each of these models is described thoroughly in the GGUM2004 Technical Reference Manual. The most general model in this family is the GGUM. The GGUM allows threshold and discrimination parameters to vary across items. Each of the seven remaining models constrains either the threshold or discrimination parameters in some manner. The GGUM2004 program references these models sequentially as Models 1 through 8:

1-- constant unit version of the generalized graded unfolding model (GGUM)

2-- multiple unit version of the GGUM

3-- rating scale version of the GGUM

4-- partial credit version of the GGUM

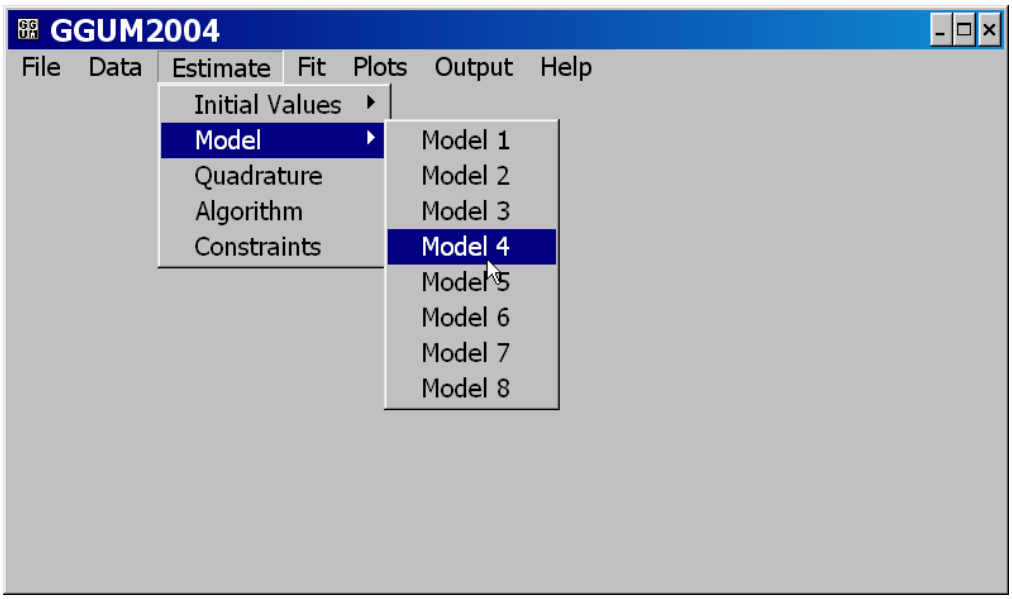
5-- generalized constant unit version of the GGUM

6-- generalized multiple unit version of the GGUM

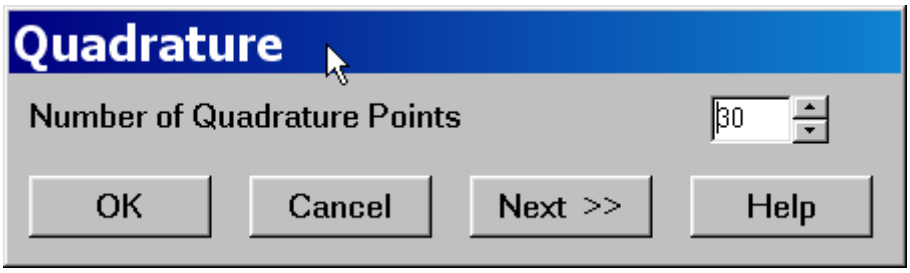
7-- generalized rating scale version of the GGUM

8-- generalized graded unfolding model (GGUM)

You can select the type of model to use in a given analysis by choosing the **Model** option from the **Estimate** pull-down menu, and clicking on one of the eight models that are subsequently listed.



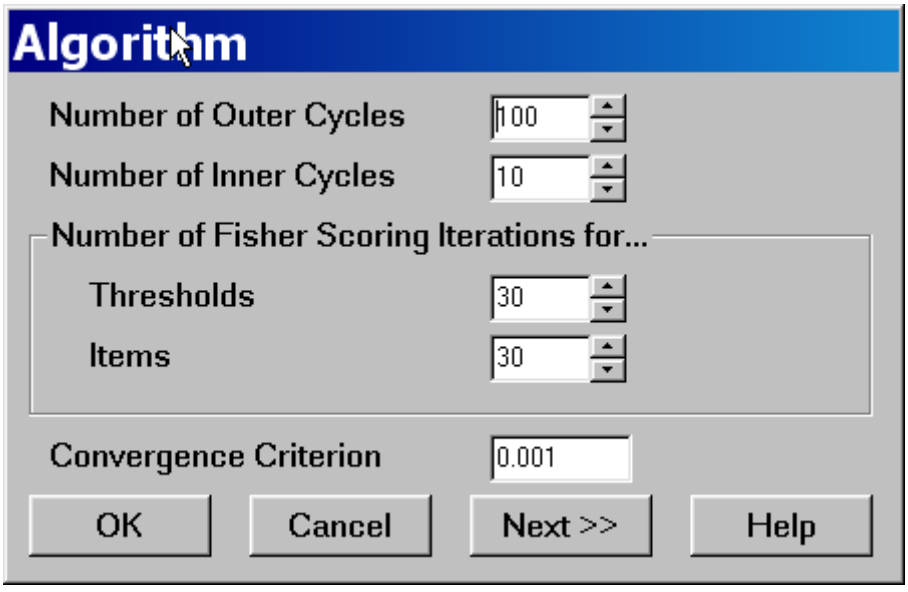
GGUM2004 uses a marginal maximum likelihood (MML) technique for item parameter estimation and an expected *a priori* (EAP) procedure for person parameter estimation. Both the MML and the EAP estimation procedures require integration over a prior distribution for θ in their respective calculations. The GGUM2004 system always integrates over a fixed normal (0, 1) prior distribution for θ. The integration is performed numerically using a series of discrete quadrature points.



You can specify the number of quadrature points used to perform this integration by clicking on the **Quadrature** option of the **Estimation** pull-down menu. The **Quadrature** option window will automatically appear. You can manually type in the number of quadrature points to use in the text box on the right side of this window. Alternatively, you can designate the number of quadrature points using the vertical bars associated with this window. ***The number you specify must be less than or equal to 50.*** Currently, 30 quadrature points are generally recommended when using GGUM2004 for common applications. The precision of the numerical integration will generally increase as the number of quadrature points increases, but the speed in which an analysis executes will become slower. The specified number of quadrature points are automatically located at equally spaced positions along the latent continuum so that they begin with -4 and end with +4. This range is constant regardless of the number of quadrature points chosen. The specified number of quadrature points will be used for both the MML and EAP estimation procedures.

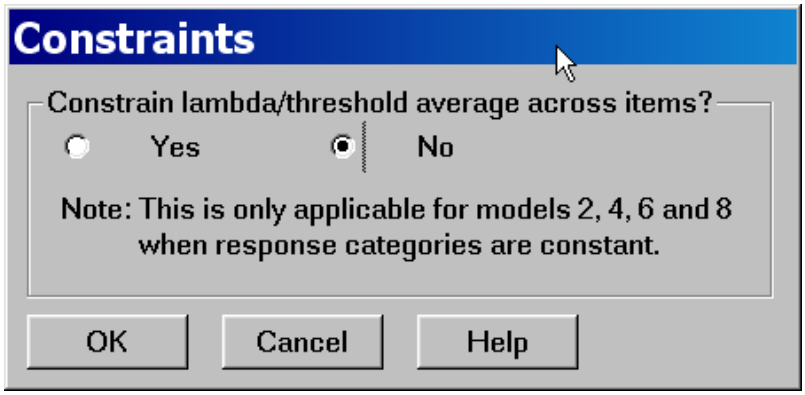
The MML algorithm is an iterative parameter estimation procedure which has two steps. In the first step, the expected numbers of respondents at a given quadrature point who chose each response category option are calculated for every item. GGUM2004 refers to this expectation step as an outer cycle. The likelihood equation is then calculated using these expectations as fixed quantities, and then the values of item parameters that maximize this likelihood equation are calculated. This latter calculation is referred to as the maximization step. The maximization step is conducted in two distinct stages. In the first stage, the estimates of thresholds ($\tau_{i\,k}$) or units (λ_i) are obtained by maximizing the likelihood using a Fisher scoring algorithm. (These

estimates may be for a single item or across all items. If the estimates are based on all items, then the *i* subscript denoted on the parameters above would be dropped.) In the second stage of the maximization step, the item location and, if necessary, the item discrimination parameters, are estimated. Again, the likelihood is maximized using a Fisher scoring algorithm. Performance of these two stages constitutes a single inner cycle. Because the results of these two stages are dependent on each other, multiple inner cycles are generally performed until there is little change in the item parameter estimates or some prespecified maximum number of inner cycles has been reached. At that point, the maximization step is complete, but it is conditional on the expectations from the preceding outer cycle. Therefore, the entire process (i.e., deriving the expectations in an outer cycle and then solving for item parameter estimates using a series of inner cycles) is repeated over and over until there is little change in the item parameters from one outer cycle to the next or until some prespecified number of outer cycles has been conducted.



The **Algorithm** option window enables you to control various aspects of the MML estimation procedure. The first text box in this window allows you to specify the maximum number of **Outer Cycles**. ***This number should be greater than or equal to 5.*** Moreover, a minimum of 100 outer cycles is often recommended because the MML algorithm is somewhat slow to converge. The second text window allows you to specify the maximum number of **Inner Cycles** that will be conducted within a given outer cycle. The current recommended value for the maximum number of **Inner Cycles** is 10. The third and fourth text boxes allow you to specify the maximum number of **Fisher scoring iterations** for the threshold/lambda parameters and item (location and/or discrimination) parameters, respectively. These maxima control the number of Fisher scoring iterations allowed within a given inner cycle. Values of 30 are recommended for each of these maxima although this is probably more than what is actually needed. The final text box allows you to specify the **Convergence Criterion** that is required in any iterative step in the MML algorithm. If the parameter estimates in that step change in absolute value by less than this amount, then that iterative step is terminated. For example, if parameter estimates in a given Fisher scoring process change in absolute values by an amount less than this criterion, then the corresponding Fisher scoring process terminates, and the next stage in the algorithm begins. Similarly, if all parameters change in absolute value by less than this amount from one inner cycle to the next, then the maximization step stops and the next outer cycle begins. Finally if all parameters change in absolute value by an amount less than this criterion from one outer cycle to the next, then the MML estimation process ends. A **Convergence Criterion** equal to .001 is currently recommended to achieve stable item parameter estimates.

Extreme items that are located far above or below the majority of respondents on the latent continuum are often difficult to estimate. This is especially true when thresholds or units are allowed to vary across items, and the number of item response categories is small. In these cases, the locations and thresholds (or units) for extreme items may begin to "trade-off" with each other and become noticeably large. When this occurs, the affected parameter estimates will also have substantially larger standard errors relative to items located closer to the distribution of respondents. GGUM2004 enables you to constrain the estimates of item-level thresholds or units so that they have fixed averaged values across items. This is accomplished by first estimating a common set of threshold parameters or a common unit parameter across all items. The associated item-level threshold or unit estimates are then recentered to the previously estimated common value(s) on subsequent iterations of the MML algorithm. This estimation strategy can be implemented using the **Constraint** option window. To implement this constraint, select the "**Yes**" button. Otherwise, click on the "**No**" button.

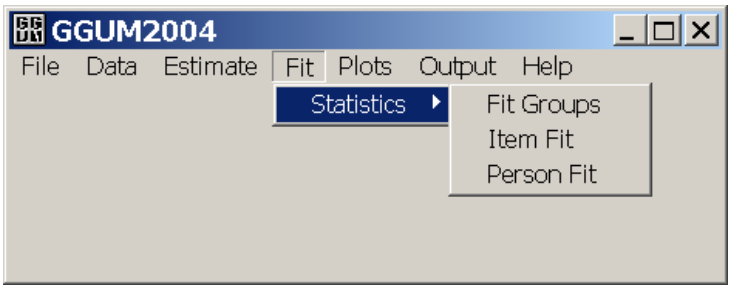


This constraint is only applicable for Models 2, 4, 6, and 8 where threshold or unit parameters are allowed to vary across items. Additionally, it can only be used when there

is a common number of response categories for all items in the analysis. Simulation studies are currently being conducted to ascertain the utility of this constraint in the context of the GGUM. In the meantime, we recommend that you avoid using this constraint unless it is clearly necessary.

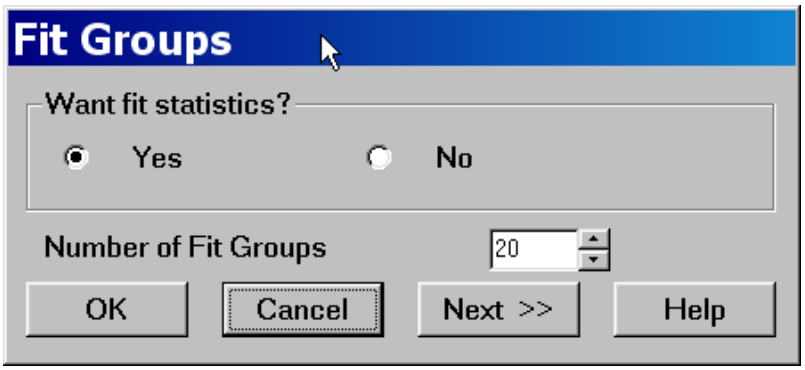
5. The Fit Pull-down Menu

GGUM2004 provides several types of item and person fit statistics. The **Fit** pull-down menu allows you to specify how these statistics are computed, printed and identified. The **Fit** pull-down menu is associated with a **Statistics** option which, in turn, has three options available. These are the **Fit Groups**, **Item Fit** and **Person Fit** options. Clicking on any of these options will activate the corresponding option window.

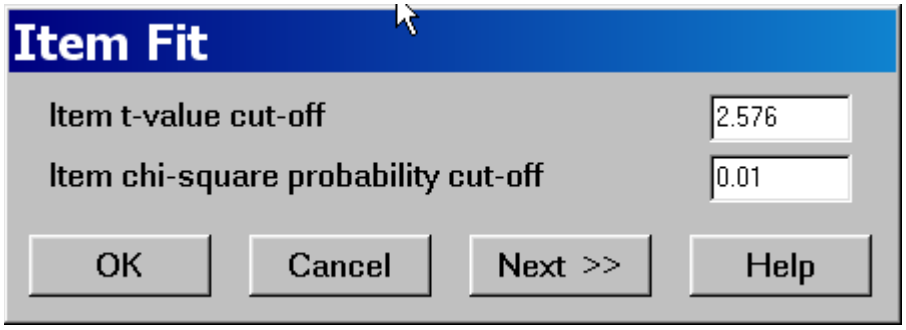


The **Fit** Groups option window enables you to request or suppress the calculation of fit statistics. To request fit statistics, click on the "**Yes**" button. Otherwise, click on the "**No**" button. One of the item fit statistics (G^2) divides respondents into homogeneous fit groups based on their estimated θ value. You can designate the number of groups that will be formed using the text box labeled **Number of Fit Groups**. You can type the number of fit groups desired into the text box or use the vertical arrow buttons to indicate this number. ***The number of fit groups should be between 2 and 20.*** The default number

of fit groups is 10. The number of fit groups should be greater than or equal to 1 plus the number of item parameters in order to calculate degrees of freedom for the G^2 statistic. Note that the number of fit groups used to evaluate the fit of a given item may be automatically collapsed by GGUM2004 if the data are sparse.



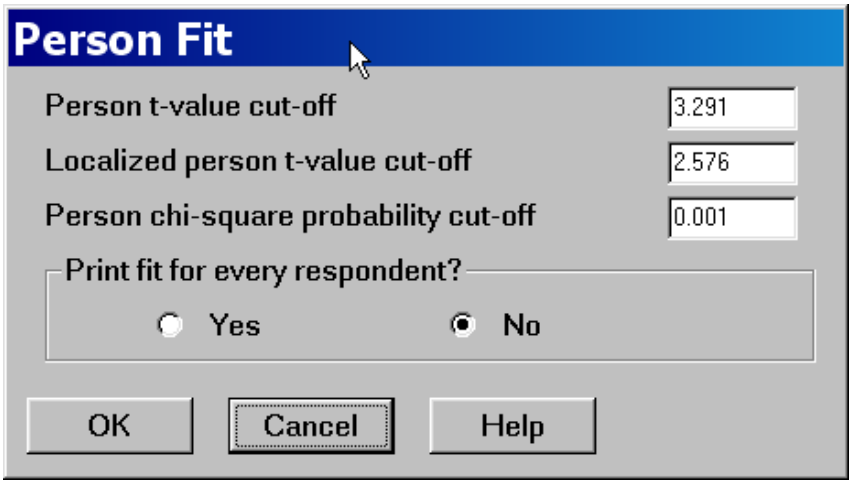
When fit statistics are requested, GGUM2004 will print out fit statistics for all items. You can define statistical cut-off values to isolate those items that show the most misfit in a given analysis. Items with fit indices that exceed these cut-off values are printed with special symbols to distinguish them from better fitting items.



The **Item Fit** option window allows you to specify statistical cut-off values for particular item fit indices. You can specify an **Item t-value cut-off** using the first text box on the right side of the window. This cut-off value will be used to highlight standardized infit

and outfit t-statistics along with the corresponding localized infit and outfit values in the output file. (See the GGUM2004 Technical Reference Manual for more information about these item statistics.) Items with absolute infit or outfit t-values greater then this cutoff will be identified in the output using the symbol "***". Items with absolute localized infit and outfit values beyond this cut-off are highlighted in the output using the symbol "^^^". A value of 2.576 is the recommended default. You can also specify an **Item chi-square probability cut-off** using the second text box. Item infit and outfit chi-square statistics with associated probability values less than or equal to this cut-off will be highlighted in the output using the symbol "+++". A value of 0.01 is the recommended default.

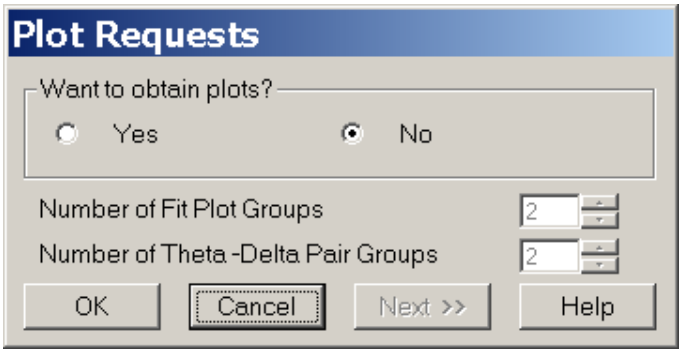
GGUM2004 calculates several different measures of person fit. You can specify cut-offs used to identify respondents with the most misfitting responses according to these measures. The first of these cut-off values is the **Person t-value cut-off**. Person infit and outfit t-statistics that are greater than this cut-off in absolute value are highlighted in the output using the symbol "***". You can also designate a **Localized**



person t-value cut-off simply by typing a value in the second text box. A cut-off value of 2.576 is recommended. Respondents with absolute localized infit or outfit indices that are larger than this value will be highlighted in the output using the symbol "^^^". You can use the third text box to specify a **Person chi-square probability cut-off**. Person infit or outfit chi-square statistics with probability values less than or equal to this cut-off will be highlighted in the output using the symbol "+++". A probability cut-off of .001 is recommended. When any of these cut-off values are exceeded, the GGUM2004 program will print the expected and observed item responses for the respondent in question along with all the fit indices mentioned above. If you would like to see this fit information for each respondent regardless of the values of the fit criteria, then click on the "**Yes**" button associated with the **Print fit for every respondent** option. Otherwise, click on the "**No**" button. You should note that requesting the fit information for each respondent can produce an enormous amount of text output.

6. The Plots Pull-down Menu

The **Plots** pull-down menu allows you to access the **Plot Requests** option window. GGUM2004 can produce a variety of graphs to assess the performance of a given model. These include item and operating characteristic curves, item and model fit plots, item and test information curves, response frequency histograms, EAP estimate distribution histograms, item location plots, and latent trait distribution plots. All of these graphs can be obtained through the **Plot Requests** option window. Simply click on the "**Yes**" button under the **Want to obtain plots?** option. If none of these graphs are desired, then click on the "**No**" button.

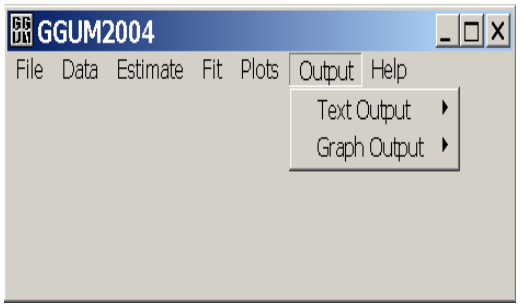


If plots are requested, then you need to specify the number of groups (i.e., points) used for item and model fit plots. For item fit plots, respondents are classified into a specified number of groups that are homogeneous with regard to their theta estimates. The number of groups must be between 2 and 20. You should specify the number of groups to be used by typing a number in the text box associated with the **Number of Fit Plot Groups** option. Alternatively, you can click on the vertical arrow bars to the right of the text box. For the model fit plots, the difference between the estimated location of each respondent and each item is calculated. These "theta-delta pair" values are sorted and then classified into a specified number of homogenous groups. The number of groups must be between 2 and 2000. To specify the number of groups (i.e., points to be used) for the model fit plot, type in the number in the text box associated with the **Number of Theta-Delta Pair Groups** option. This number can also be specified using the vertical arrow buttons to the right of the text box.

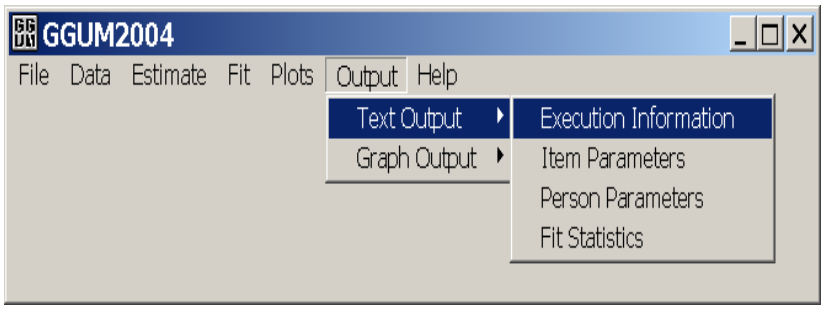
7. The Output Pull-down Menu

GGUM2004 can produce two kinds of output - text output and graphics output. You can display, save and print both types of output using options provided in the

Output pull-down menu. If the **Text Output** option is chosen, then you can view

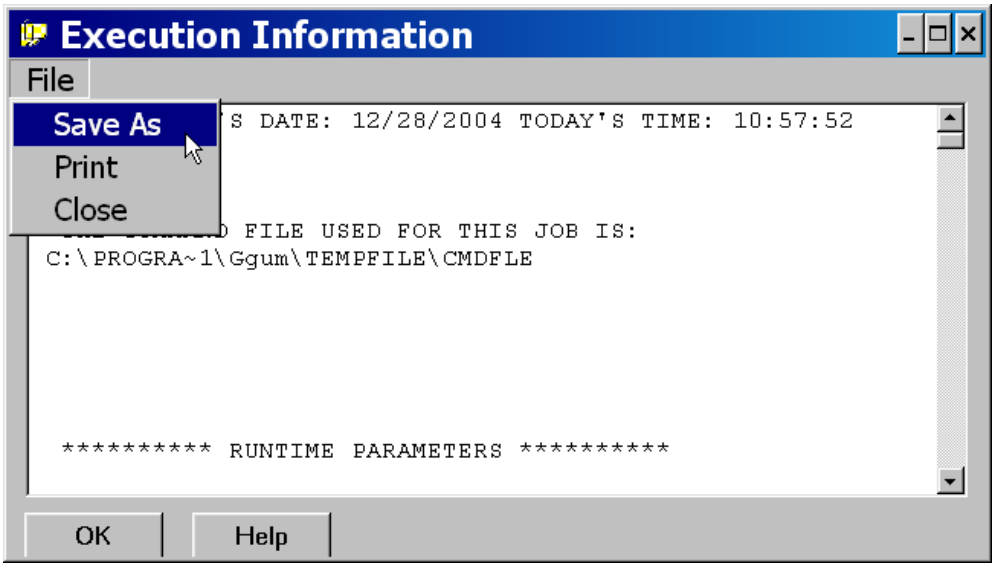


one of four types of text output files produced by the program. These include **Execution Information, Item Parameters, Person Parameters and Fit Statistics**. Each of these output files is stored in the GGUM2004 temporary directory under the names FT06F001, FT16F001, FT17F001, and FT15F001 respectively. They are automatically deleted when the **New, Open, Run,** or **Exit** options are chosen from the **File** pull-down menu. The

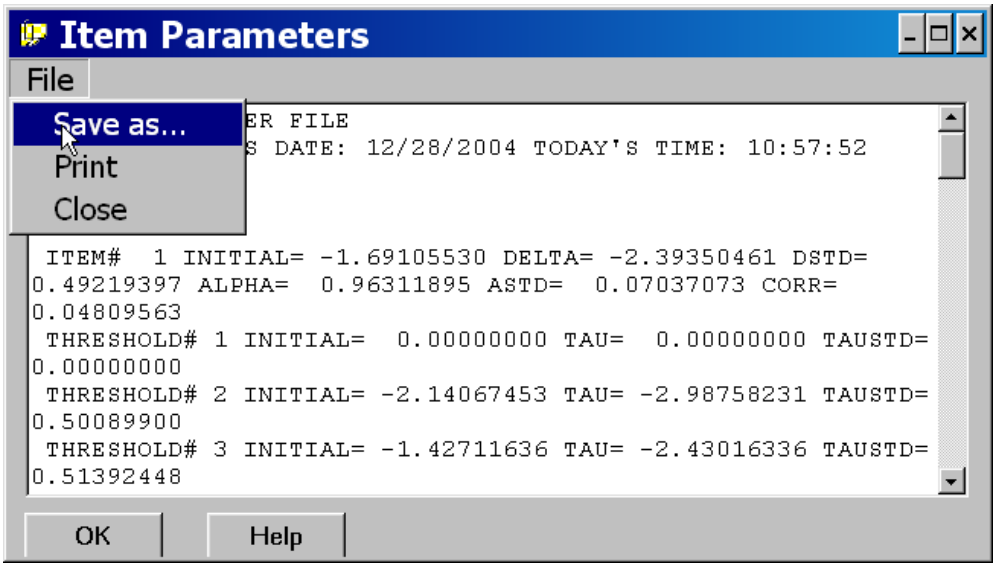


format of each file is described in the GGUM2004 Technical Reference Manual. Examples of the four text output windows are shown below:

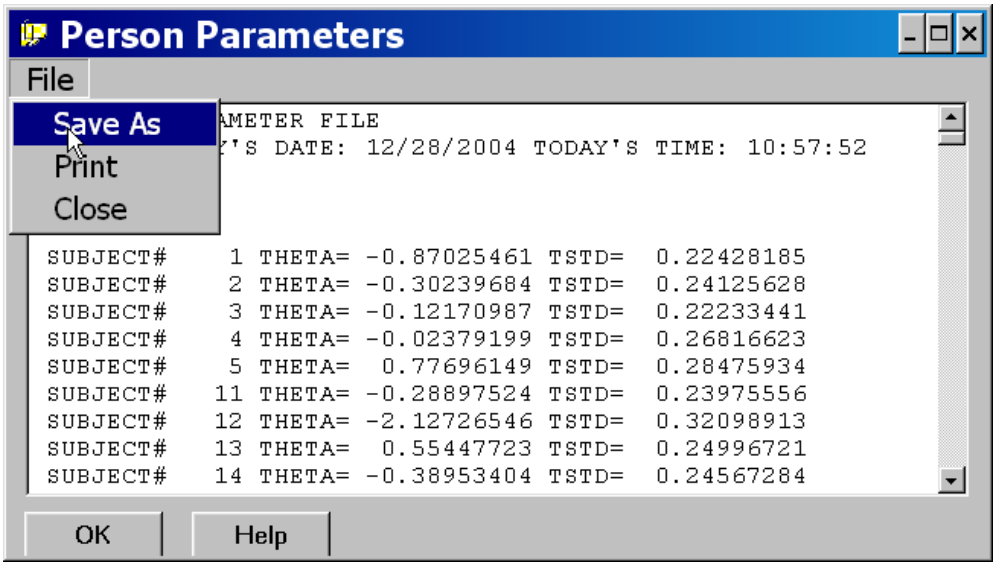
a) Execution information.



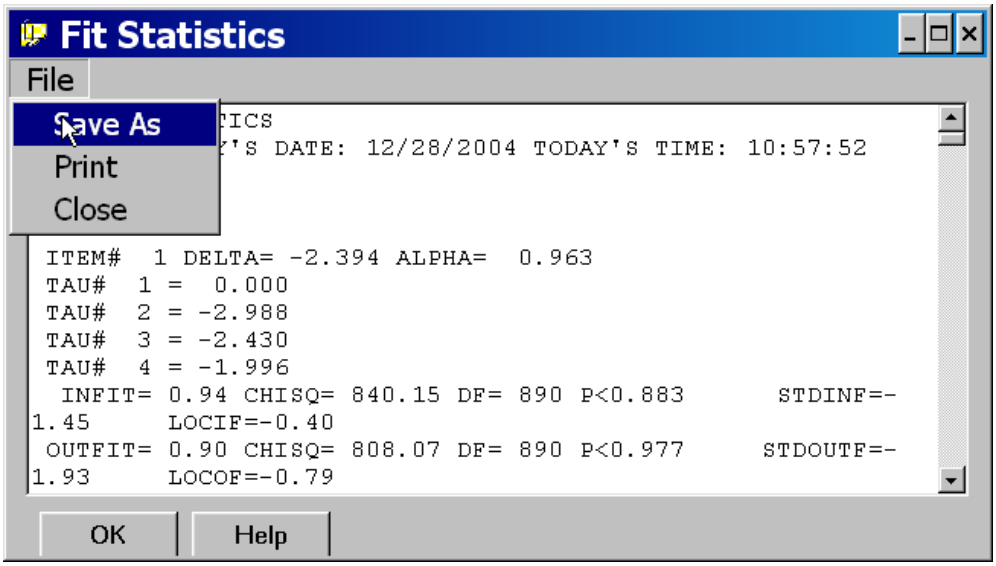
b) Item Parameters



c) Person Parameters



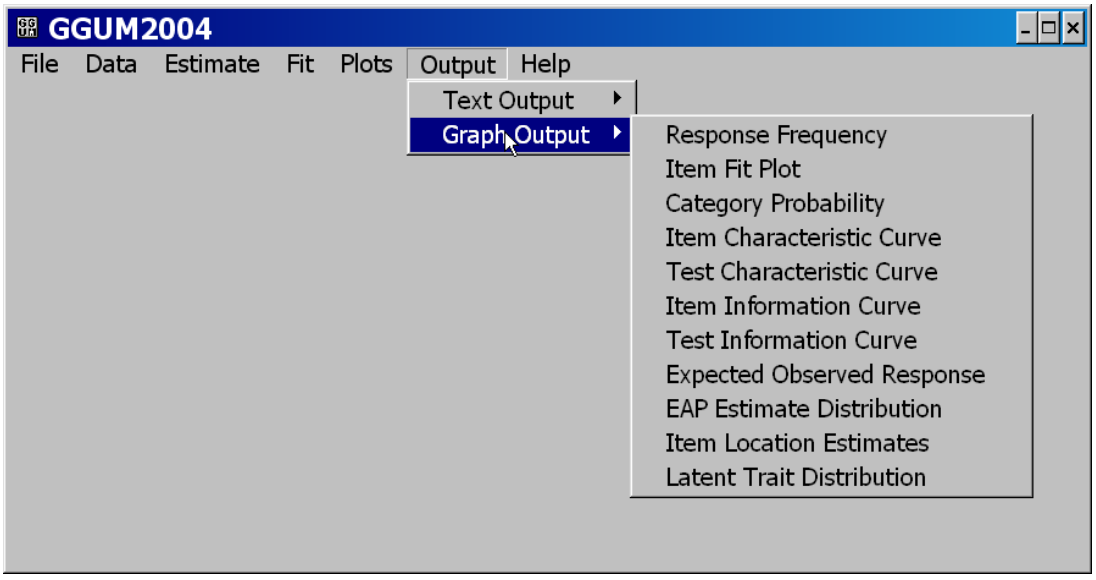
d) Fit Statistics



Notice that each text output window has a pull-down menu that enables you to save the file (**Save As**), print the file (**Print**), or close the text window (**Close**). You can also

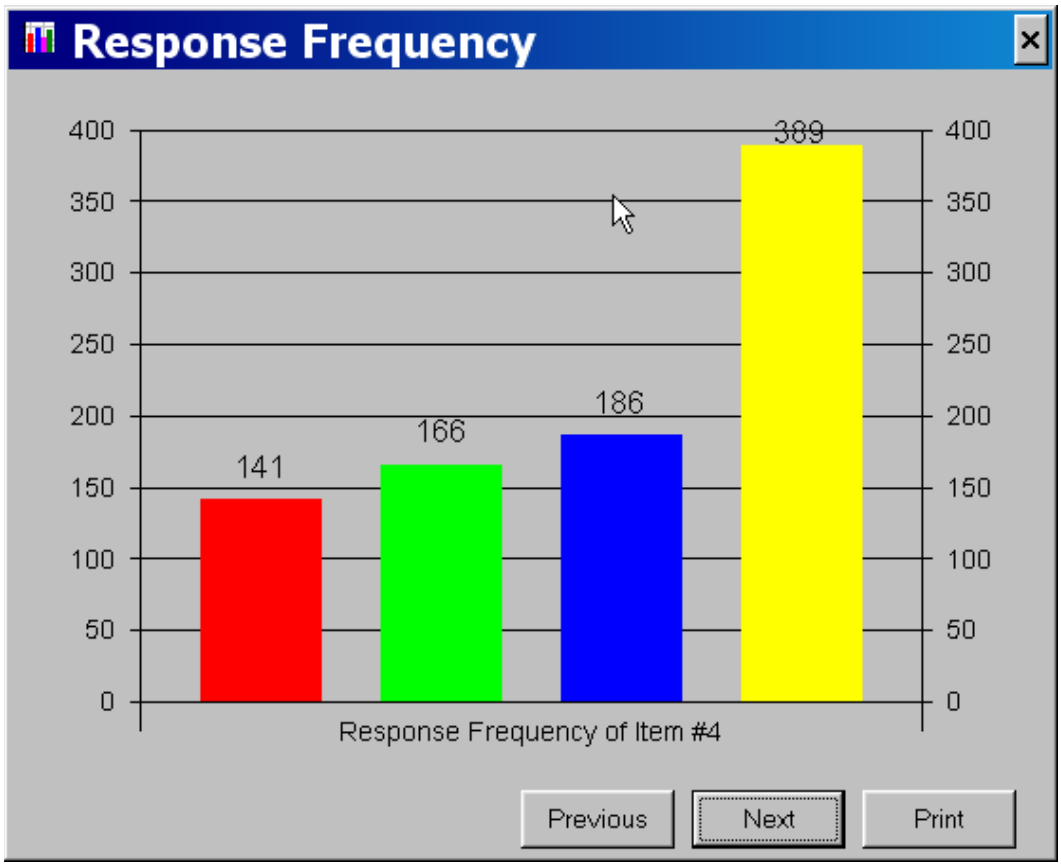
close the window by clicking on "**OK**". The content displayed in each of these output windows is explained in the GGUM2004 Technical Reference Guide.

Eleven types of graphs can be accessed through the **Graph Output** option in the **Output** pull-down menu. Each type of graph is associated with a particular option which is labeled as **Response Frequency**, **Item Fit Plot**, **Category Probability**, **Item Characteristic Curve**, **Test Characteristic Curve**, **Item Information Curve**, **Test Information Curve, Expected Observed Response, EAP Estimate Distribution, Item Location Estimates,** and **Latent Trait Distribution**, respectively. Several of these graphs provide information at the item level, and thus, there is a different graph for each item. These include the graphs associated with the **Response Frequency, Item Fit Plot, Category Probability, Item Characteristic Curve,** and **Item Information Curve** options. These item-level graphs have "**Previous**" and "**Next**" options that enable you to view the entire series of graphs for the items under analysis. Each type of graph also has a "**Print**" option that will send a copy of the graph to the Windows default printer. Finally, all graphs other than the **Response Frequency** graphs have a "**Save As**" option that enables you to save the graph to disk in a bitmap graphics format.



Examples of the eleven graph output windows are given below:

a) Response Frequency - GGUM2004 produces a bar chart of response frequencies for each item. You can print these graphs, but they cannot presently be saved to disk.



b) Item Fit Plot. Respondents are classified into a specified number of groups that are homogeneous with regard to their theta estimates. The number of groups is specified in the **Number of Fit Plot Groups** in the **Plot Requests** option window described earlier. The average observed item response is plotted against the average estimated theta value for each respondent group. The average observed item response value for each group is depicted by a dot. Additionally, the average expected value in each group is connected by a solid line. A pseudo-confidence interval is represented by the "whiskers" emanating vertically from each expected value. This interval is defined for the *ith* item in the *jth* respondent group as:

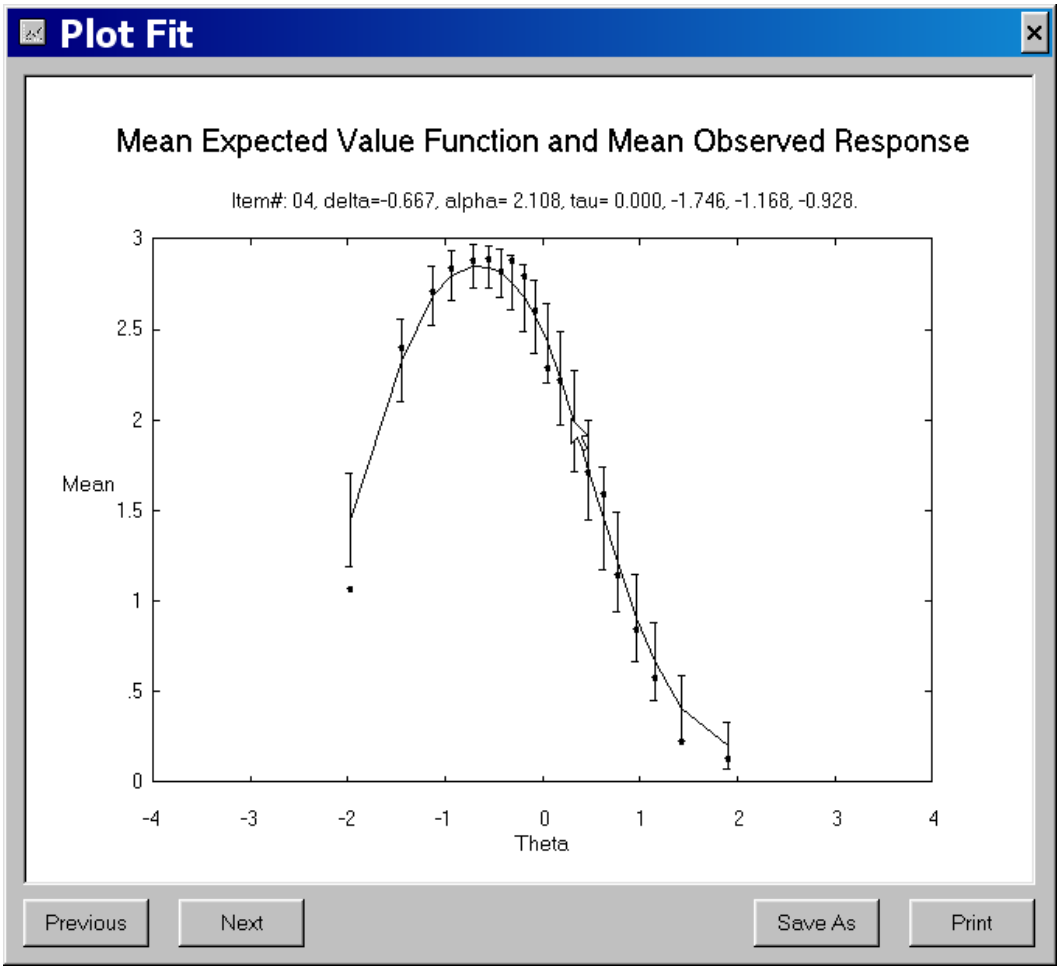
$$\pm 2 * \sqrt{\sum_{j=1}^{n_j} \hat{\sigma}_{ji}^2 / n_j}$$

where:

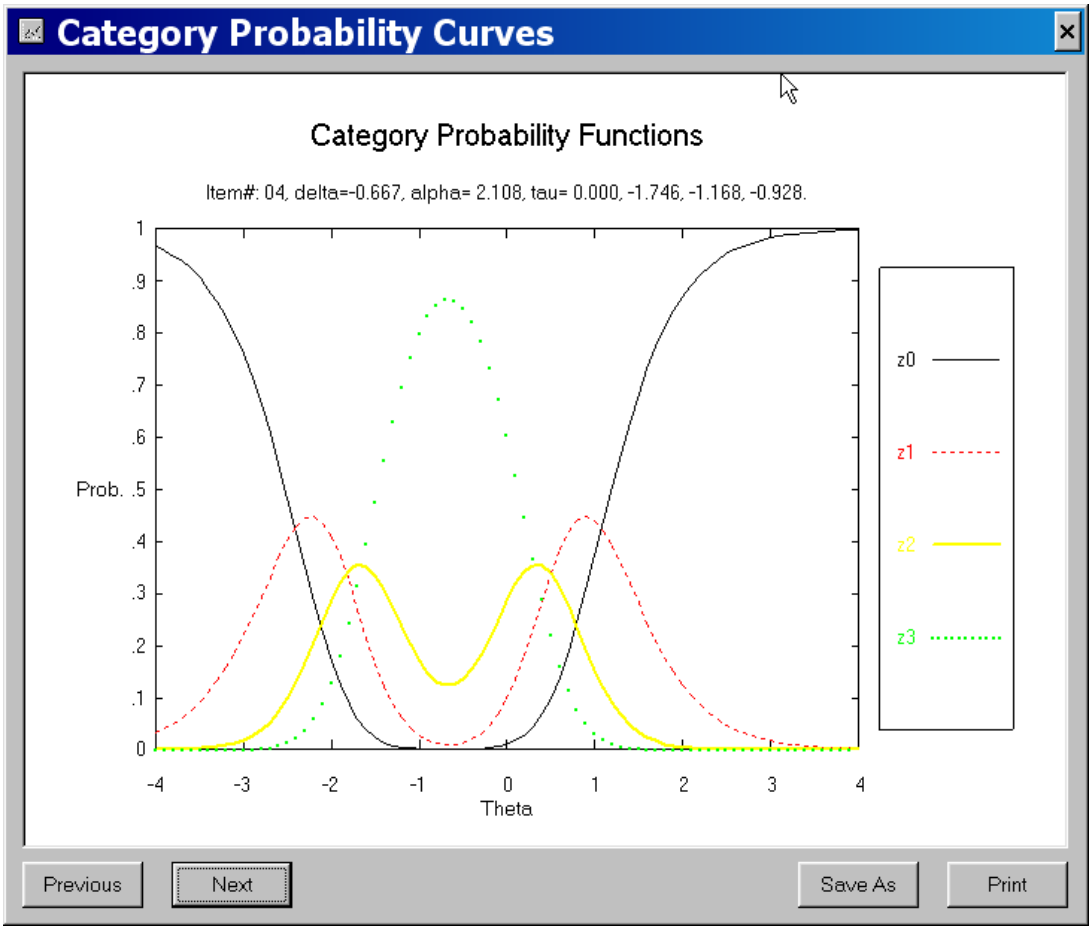
n_j = the number of respondents in the *jth* fit group and:

$$\hat{\sigma}_{ji}^2 = \sum_{w=0}^{C_i} [P_i(w \mid \hat{\theta}_j)\{w - [\sum_{z=0}^{C_i}(z * P_i(z \mid \hat{\theta}_j))]\}^2].$$

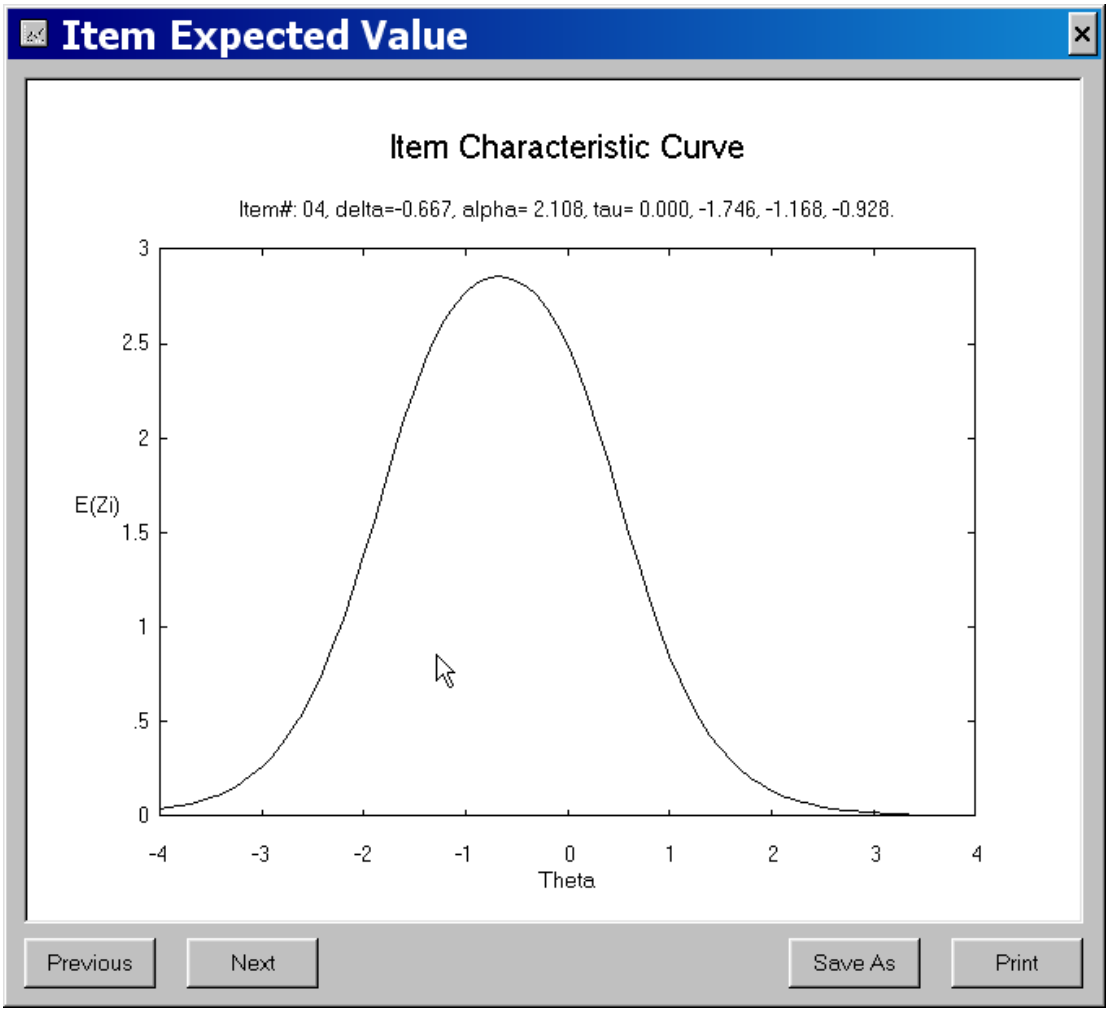
Thus, the pseudo-confidence interval is equal to plus or minus 2 times the square root of the average variance of an observed score for respondents in a given group. Each graph is labeled with the item number and the values of the corresponding GGUM item parameter estimates. Discrepancies between the dots and the solid line represent item misfit between the model and the data. This is especially true when there are many dots outside of the confidence intervals and/or the deviations form a pronounced systematic pattern. However, you must remember that the variability in the average values portrayed in these graphs is dependent on the number of data points used to form each average value. This, in turn, is determined by the sample size and the value specified for **Number of Fit Plot Groups**. Experience has shown us that this graph is a valuable tool to assess item fit.



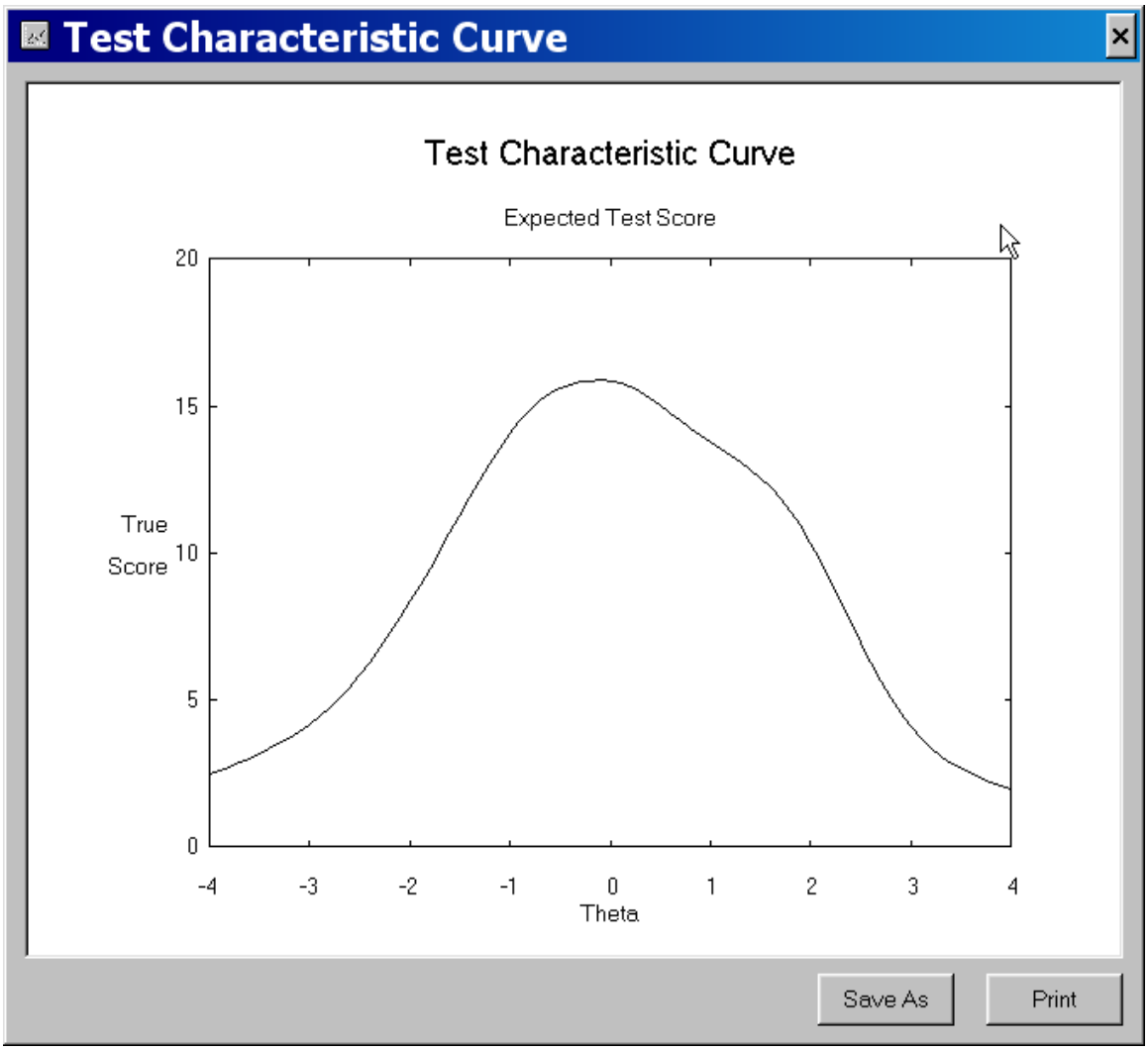
d) **Category Probability Curves**. The GGUM provides the conditional probability that a particular category will be chosen given the item parameters and a value for θ. These graphs display category probability curves (a.k.a. operating characteristic curves) for each item given the item parameter estimates. They are useful to determine how specific response categories are operating across the latent continuum.



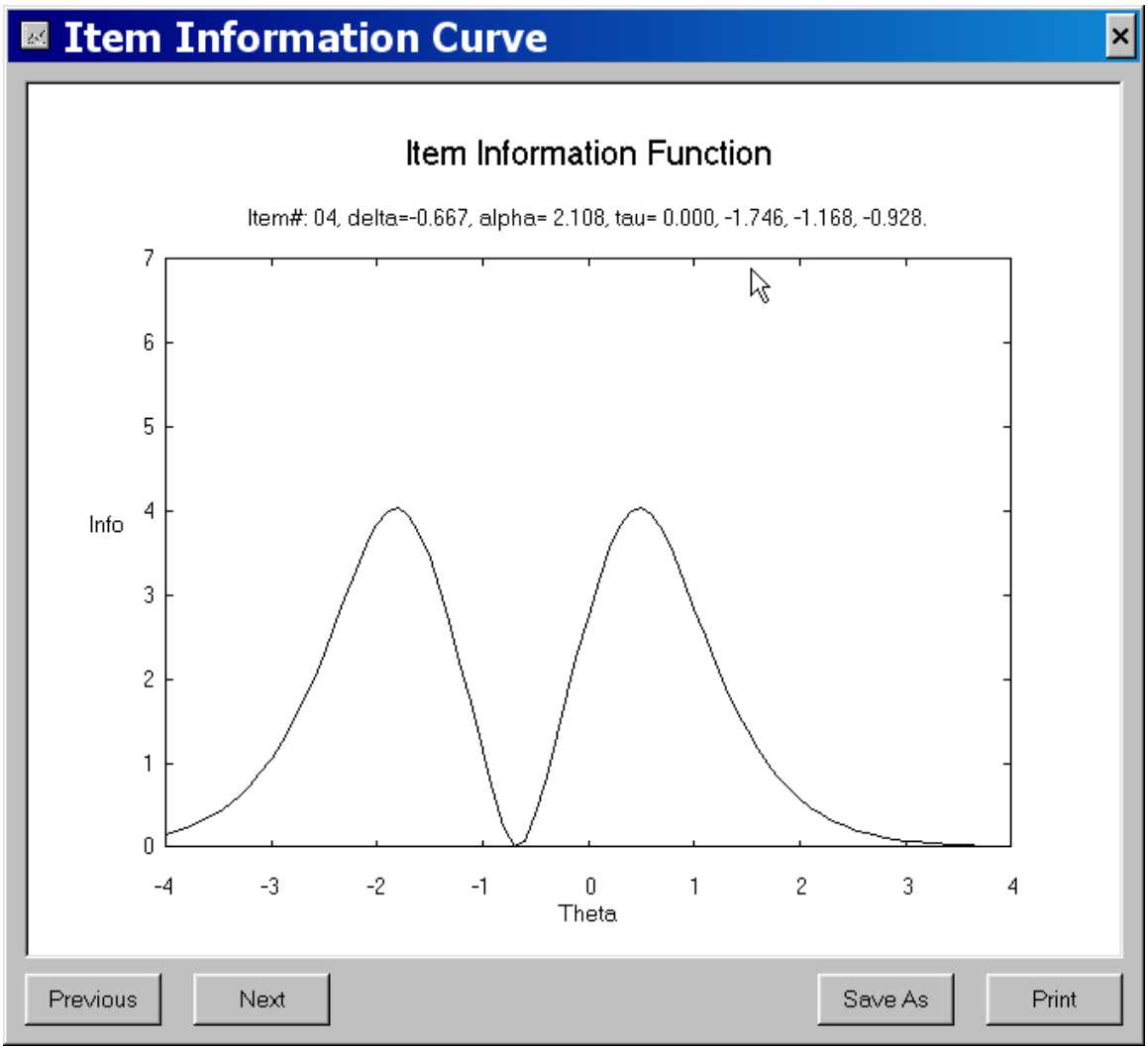
d) **Item Characteristic Curve**. The GGUM item parameter estimates can be used to produce item characteristic curves for each item. Each curve represents the expected item response (i.e., averaged over categories) given theta and the item parameter estimates for that item. Unlike the item fit plots discussed above, each expected value point is based on one hypothetical θ value rather than the average expected value derived empirically across a group of respondents. This graph is useful to assess the manner in which the item functions across the latent continuum.



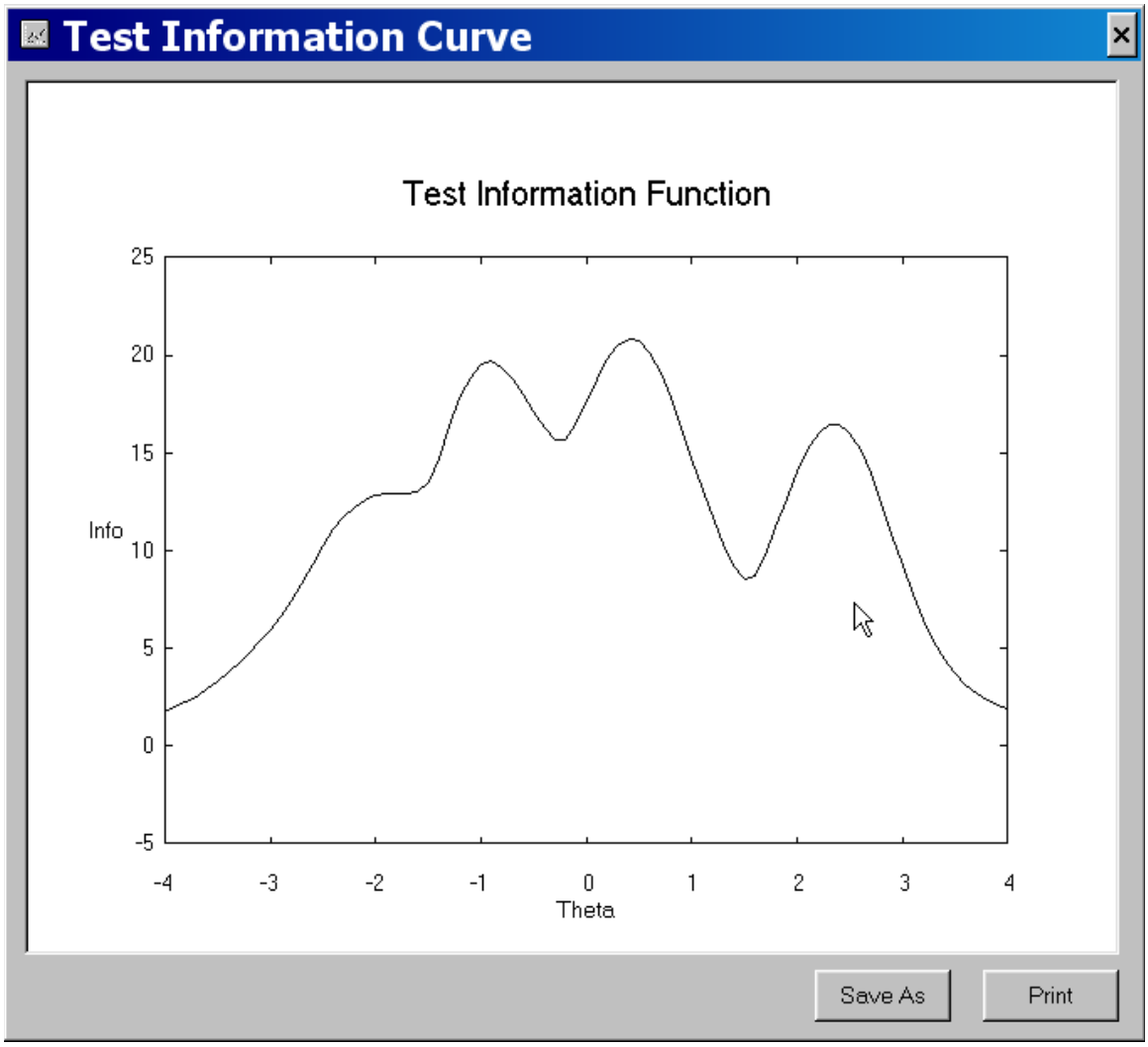
e) **Test Characteristic Curve**. GGUM2004 produces a test characteristic curve (TCC) based on all of the items in the analysis. A TCC portrays the expected total score (i.e. expected summated score) given a particular value for θ. Note that the expected total score at a given level of θ is simply the sum of the item characteristic functions at that value of θ. The expected total score is identical to the notion of a "true score" in classical test theory.



f) **Item Information Curve**. GGUM2004 plots item information curves for each item. These curves are generally bimodal with modes to the left and right of δ_i. The information is equal to zero when $\theta = \delta_i$ and when $\theta - \delta_i$ approaches negative or positive infinity. Details about the item information function can be found in Roberts, Donoghue and Laughlin (2000).

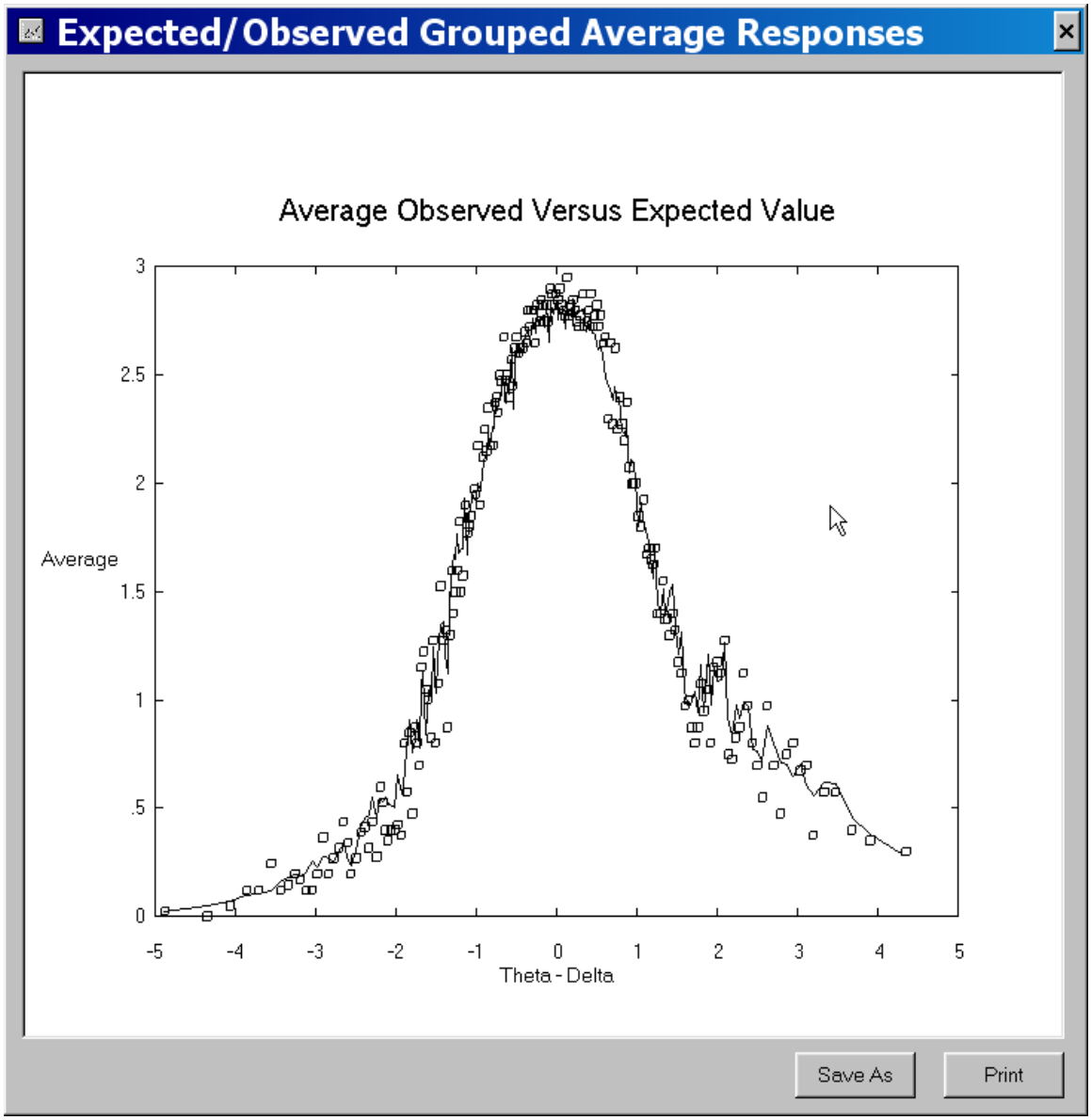


g) **Test Information Curve**. GGUM2004 also plots the test information function (TIF) for all of the items in the analysis. The TIF is simply the sum of all item information functions at a given value of θ. The TIF is the inverse of the variance of the maximum likelihood estimate for θ. As such, it provides an indication of how well a set of items can measure respondents located at various points on the latent continuum. (Note that GGUM2004 produces EAP estimates of θ rather then maximum likelihood estimates. Nonetheless, high test information generally leads to more precise EAP estimates.)

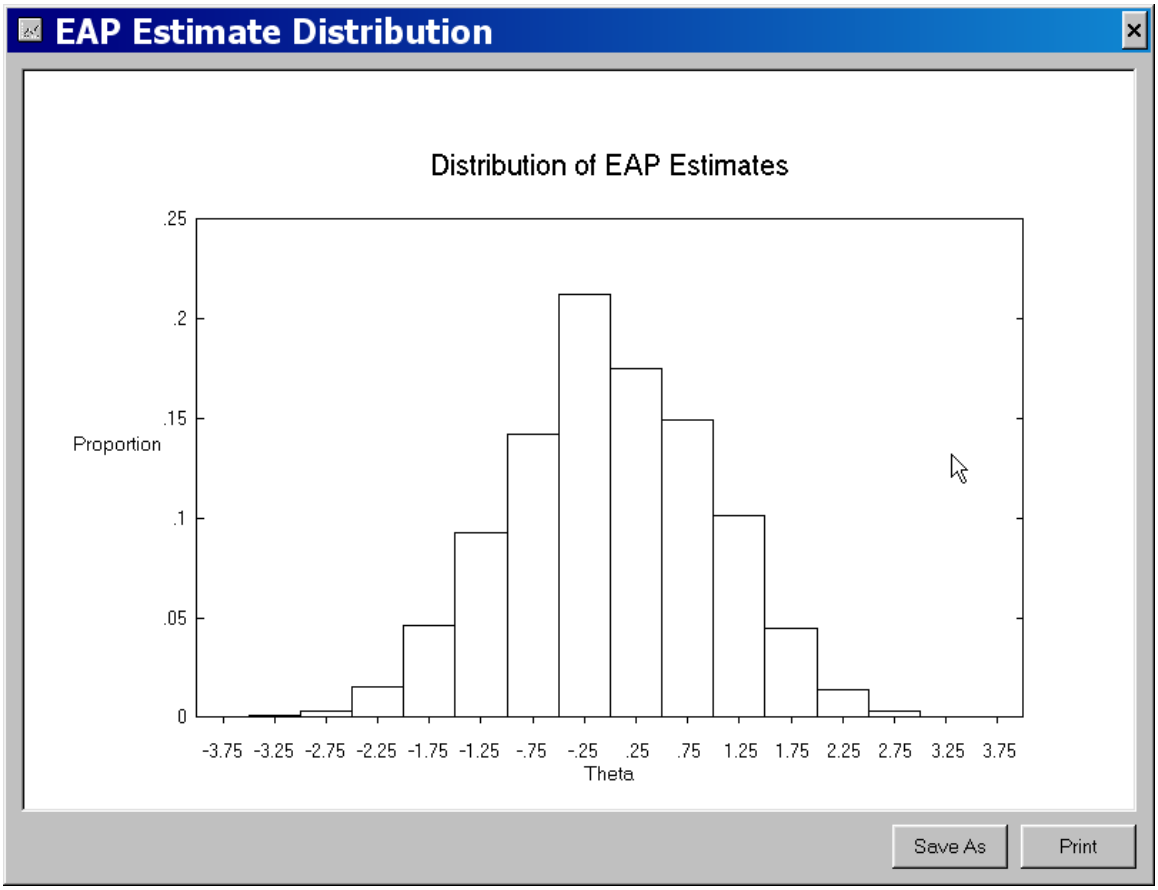


h) **Expected/Observed Grouped Average Responses**. The plot of expected/observed grouped average responses is an attempt to provide visual evidence about the fit of a given model to the observed data. To construct this plot, the signed difference between each respondent's location and each item's location is calculated. These theta-delta differences are sorted and then classified into a specified number of homogenous groups. (The number of groups is specified in the **Number of Theta-Delta Pair Groups** option in the **Plot Requests** option window.) The average observed item

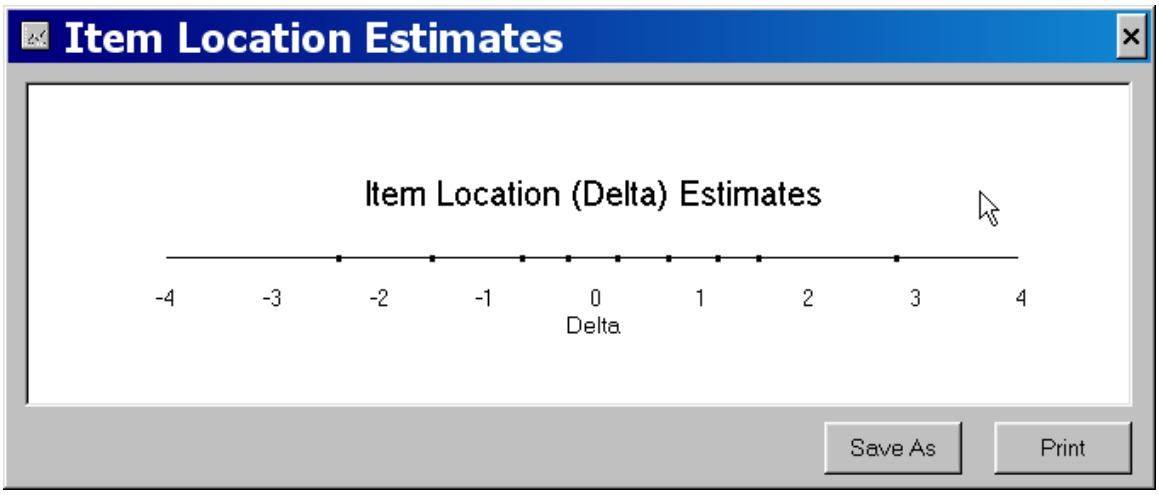
response and average expected item response is then calculated for all person/item pairs in a given group. The average theta-delta value is also calculated. The average observed and expected item responses are then plotted against the average theta-delta value. The empty squares in the graph represent the average observed item response for each group whereas the solid line represents the average expected item response. Model fit is suggested to the extent that the solid line coincides with the empty squares.



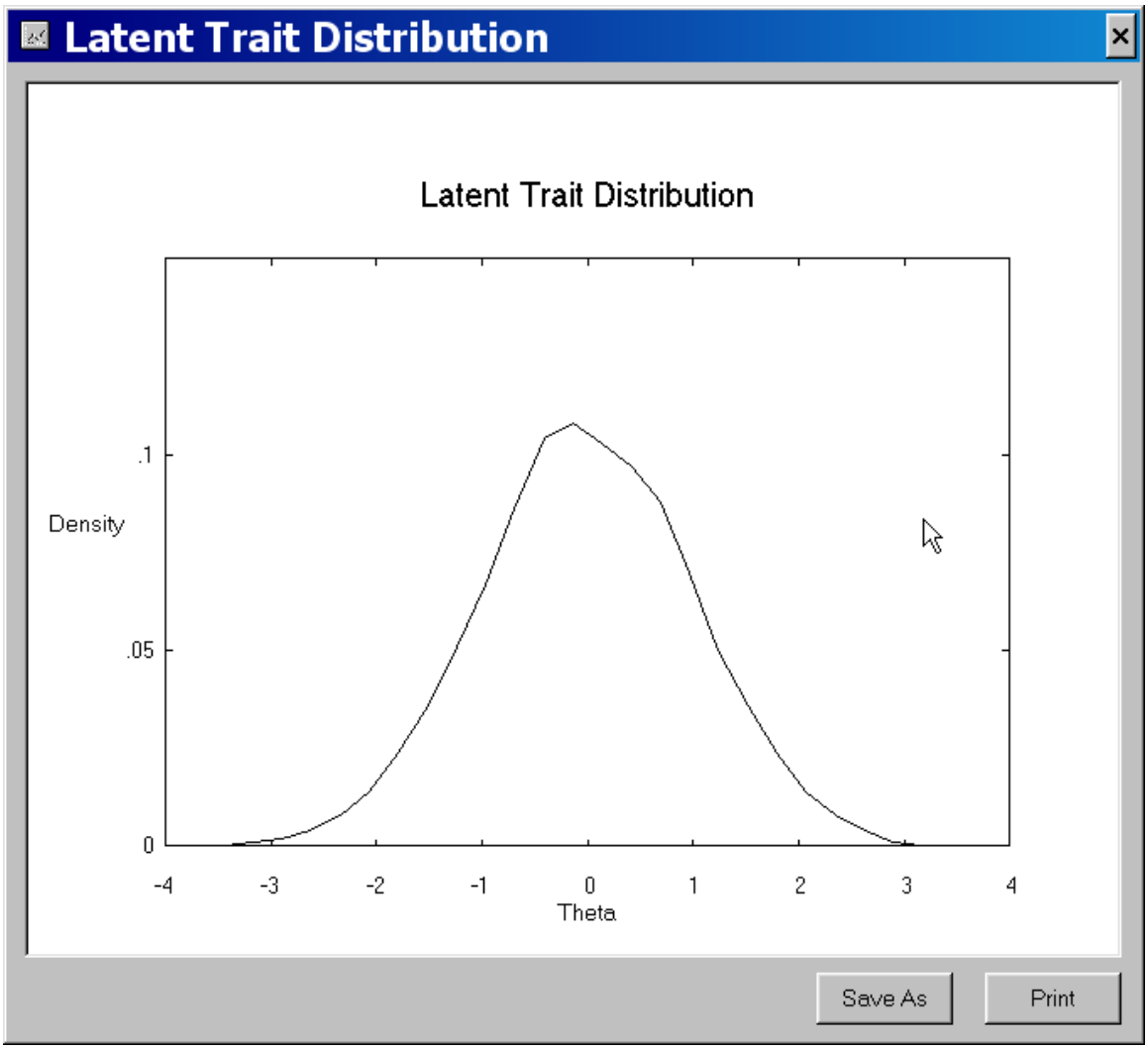
i) **EAP Estimate Distribution.** GGUM2004 estimates θ parameters using an expected *a posteriori* (EAP) technique. (These estimates are thoroughly described in the GGUM2004 Technical Reference Manual.) The distribution of the estimated θ values is displayed using a bar chart where the horizontal axis represents the latent trait (i.e., θ) and the vertical axis represents the proportion of the respondents at that point on the latent continuum. To develop this graph, the θ values are first grouped into .5 unit intervals between -4 and +4, and then the proportion of respondents in each interval is calculated. This proportion is displayed against the midpoint of the θ interval.



j) **Item Location Estimates**. This graph plots estimated item locations (i.e., δ_i estimates) on a vector which represents the latent continuum. This enables you to see how well a given set of items represents the latent continuum. When developing a questionnaire, a uniform distribution of items across the continuum is desired.



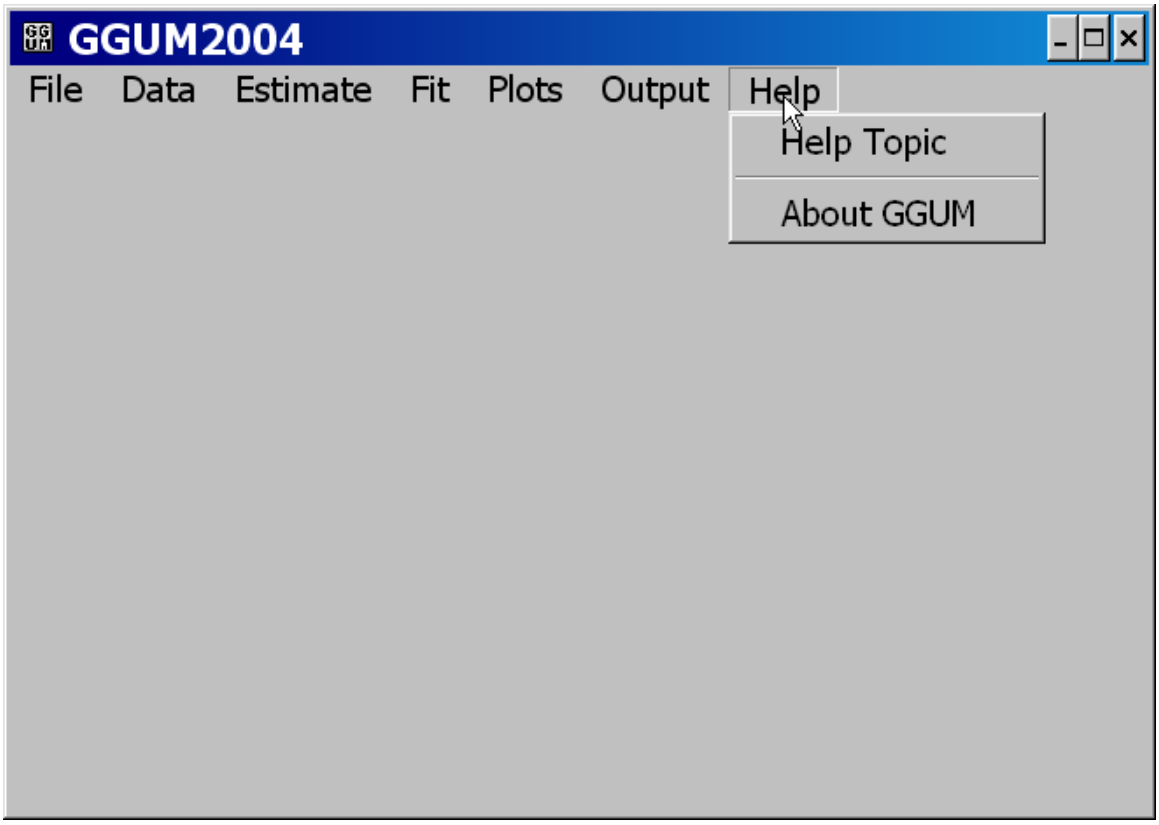
k) **Latent Trait Distribution.** GGUM2004 also plots the estimated latent trait distribution (a.k.a. the estimated population distribution of θ). This is identical to a plot of the posterior density of θ at each quadrature point on the final iteration of the MML item parameter estimation algorithm. Unlike the distribution of EAP estimates, the estimate of this distribution does not suffer from shrinkage toward the mean of the prior distribution.



8. The Help Pull-down Menu

The **Help** pull-down menu provides access to basic information about the GGUM2004 program and access to the help windows that are part of the graphical user

interface. Information about the program can be obtained by clicking on the **About**



GGUM option. Similarly, one can click on the **Help Topic** option to obtain a hyperlink list of the 19 help windows in the GGUM2004 system. When the **Help Topic** option is chosen, the following HTML screen appears:

Help Topics:

1. Algorithm
2. Choose Items to Delete
3. Choose Respondents to Delete
4. Constraints
5. Delete Items
6. Delete Respondents
7. Execution Information

8. Fit Groups
9. Fit Statistics
10. Item Definitions
11. Item Fit
12. Item Parameter Estimates
13. Person Fit
14. Person Parameter Estimates
15. Plot Requests
16. Quadrature
17. Read Data
18. Response Category Definitions
19. Response Cutoffs

When you click on any of these hyperlinks, the associated help file will be displayed by your default HTML browser. The help files can also be activated in a context-sensitive mode by clicking on "**Help**" from within the relevant GGUM2004 option window.

9. The GGUM2004 Examples Folder

When you install the GGUM2004 program, you have the option of copying a set of example command files and an example data file to a folder called "C:\GGUM2004\EXAMPLES". This folder contains 8 command files named "CMDFLE1", "CMDFLE2", …, "CMDFLE8". The files correspond to models 1 through 8 in the GGUM2004 system. Each file analyzes an example dataset with 25 items and

1100 respondents. The example data set consists of item responses that were simulated using Model 8 (the full GGUM).

10. Uninstalling the GGUM2004 Program

There are generally several steps to follow when uninstalling the GGUM2004 system. First, you should uninstall GGUM2004 using the "Add or Remove Programs" feature of the Windows operating system. This feature is located in the Windows Control Panel. In most cases, the "GGUM" program folder will remain in the subdirectory in which it was initially installed. By default, the installation subdirectory is "C:\Program Files". Thus, you should look for a subdirectory called "C:\Program Files\GGUM", and if it exists, then you should delete it. Additionally, you should also delete the "C:\GGUM2004" folder which contains the examples and manuals for the program. Finally, you should also delete the "GGUM_INSTALLABLE" folder and the "INSTALLGGUM.PDF" file from the root directory of your hard drive. ***Note that you must complete the uninstall process before reinstalling the GGUM2004 program or upgrading to a more recent version of the program.***

11. References

Bock, R. D., & Aitkin, M. (1981). Marginal maximum likelihood estimation of item parameters: Application of an EM algorithm. *Psychometrika, 46*, 443-459.

Bock, R. D., & Lieberman, M. (1970). Fitting a response model for *n* dichotomously scored items. *Psychometrika*, *35*, 179-197.

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